Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.7, 2013

Determinants of Household Water Quality in the Tamale Metropolis, Ghana

Daniel Boateng [1*] Martha Tia-Adjei[2] Ellis Adjei Adams[3]
1. Department of Community Health, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
2. Environmental Health and Sanitation Directorate, Tamale, Ghana
3. Department of Geography, Michigan State University, USA
* E-mail of the corresponding author: kingdannie@gmail.com

Abstract
Improved water source is essential for the health of both urban and rural dwellers. However, Over 1 billion people globally are without access to clean water and adequate sanitation facilities. The purpose of this study was to assess the factors that influence water quality in the Tamale metropolis, Ghana. The study was conducted with 250 respondents who were randomly sampled and interviewed. Data was analyzed with STATA 11 software. Chi-square and multivariate regression analysis were used to investigate the relationships between socio-demographic characteristics, water source, and water collection and storage methods and household water quality. Two assays of water quality were used: heterotrophic plate count (HPC) for total coliform and feacal counts and the multiple tube method for *Escherichia Coli* (E coli). The study results shows that majority of samples tested had feacal coliforms. Water from 83% of studied samples tested positive for the presence of E coli in household water. Source of water, distance to water source, place and duration of water storage influenced household water quality. Households with water source outside homes were less likely to have quality water (OR=0.19; $p<0.01$). On-the-point household treatment strategies should be adopted to make water safe for household consumption.
Keywords: Household, Quality, Storage, Tamale, Water, Ghana

1. Introduction

Water is identified as one of the most important natural resources because it is viewed as key to prosperity and wealth (Arbués *et al* 2003). The World Health Organization defines improved water source as one that is protected from outside contamination (WHO/UNICEF, 2010). Although an increasing number of people have access to improved water, rapid urban population growth in the Sub-Saharan African region has equally increased the number of people without proper access to water (WHO/UNICEF, 2010). Data from the World Health Organization (WHO) indicates that 87% of the world's population, and 84% of the population living in the developing world now use drinking water from safer and improved sources (WHO, 2010). Fifty-seven percent of the world's population also gets their drinking water from a piped connection that provides running water in their homes or compound. However, in Sub-Saharan African, just 60% of the population uses improved sources of drinking-water (WHO, 2010). The main sources most especially in African countries are from boreholes, pipe borne, deep and shallow wells, dug outs, streams, rivers which are mostly of poor quality. Water quality is a growing concern throughout the developing world (UNICEF, 2012) and sources of drinking water are constantly under threat from contamination. This has both public health consequences as well as socioeconomic implications (UNICEF, 2012). Faecal contamination of drinking water is a major contributor to diarrhea, water borne disease responsible for the death of millions of children every year (UNICEF, 2012).

Ghana is faced with a problem of access to clean drinking water and sanitation systems contributing to 70% of diseases in the country (AfDB/ OECD, 2007). Consequently, households without access to clean water are forced to use less reliable and hygienic sources, and often pay more for unsafe water than the wealthy (AfDB/ OECD, 2007). According to a World Vision Report in 2008, about 48% of the total population does not have access to portable water. The main sources of portable water are from piped sources and mechanized boreholes. In the Tamale metropolis, it is estimated that only about 53% of the population have access to portable water while the rest of the population depend on dams, open wells and dug outs which are often contaminated with faecal matter for their domestic use (CWSA, 2010). Albert et al (2010) in their study to determine the quality of water at the point of use (POU) discovered that Surface waters (earth pan and river) had significantly more E. coli than harvested rainwater and standpipe (tap) water. Despite the availability of clean water from taps, boreholes and tanks, problems are often experienced with accessibility and availability (Jagals, 2006). This scarcity and inconsistency in the supply of portable water especially in developing countries leads to the inevitable practice of households storing water for future use in containers. More often than not, water is not used completely that same day but stored in plastic, metal, concrete reservoirs and earthenware containers which influence water quality (Levy et al, 2008; Mintz et al. 1995). Storage duration mostly range from days to months depending on the sizes of the storage containers used and the number of users in a household. In the Tamale

Metropolis, although a little over half of the population has access to safe water, little is known about the quality of the water at the domestic level and how storage practices might influence it. This study sought to fill the gap by assessing the determinants of water quality in the Tamale metropolis.

2. Study Setting and Methods

This study was carried out in all the three sub-metropolitan areas (North, South, Central) within the Tamale Metropolitan area of Ghana with an estimated total population of 377,165. Tamale is one of the twenty administrative and political districts in the Northern Region of Ghana and also serves as the regional capital. The common diseases in the metropolis are malaria, gastroenteritis and diarrhea (GHS, 2010). The major source of water for domestic uses is derived from pipe borne water which serves about 52% of the entire population in Tamale. The rest of the population depends on hand dug wells, boreholes especially for those in the educational institutions and a few depend on dams and deep tube wells for water.

A multi stage sampling technique was used to recruit respondents for the study. First, a simple random sampling technique was used to select four communities from each of the three sub-metropolitan areas making a total of twelve communities. Simple random technique was used to select the respondents at the household level. The target population was defined and restricted to include all household heads 18years and above within the selected communities. However, in instances where the household head was absent, the next adult (eighteen years and above) was interviewed. In cases where we did not find any person in an eligible house, the immediate next house was considered and interviewed as well as water samples taken. A total of 250 household heads were interviewed for the study.

2.1 Sample analysis

Samples were collected from water storage receptacles into sterilized sample containers which were autoclaved at a temperature of 121 degree Celsius from each household. All samples were then collected into ice coolers and iced blocks put on them in other to sustain micros life. Samples were taken to the laboratory within four hours each day to preserve the sample for analysis. Two assays of water quality were used; heterotrophic plate count (HPC) for total coliform and feacal counts and the multiple tube method for *Escherichia Coli*. All results were read after 24 hours of incubation at 37degree Celsius for feacal and total coliform count and 42 degree celsius for E coli.

2.2 Data collection and statistical analysis

We used a questionnaire to collect the data. This questionnaire asked for specific factual information concerning the respondents' sources, collection and storage of water as well as certain socio demographic characteristics. Data collected was entered on SPSS version 19 and analyzed using STATA 11. Demographics, water sources, collection and storage were assessed using descriptive statistics, and chi-square analysis. A multivariate analysis of factors influencing household water quality was assessed with a logistic regression.

3.0 Results

Result from the sample analysis indicates that 19.6% of the household water tested had no feacal coliforms, 29.9% had feacal coliforms of 1- 10 counts per ml, 30.9% 11 – 100 counts per ml and 19.6% more than 100 counts per ml. Water from 83% of studied samples tested positive for the present of E coli in household water.

3.1 Socio- demographic factors and household water quality

Majority of respondents in this study were non-literate. None of the socio-demographic variables had significant influence on household water quality in the bivariate analysis, Table 1. Water quality was however higher among respondent who were non-literate than those who were literates (61.5% versus 38.5%).

3.2 Relationship between source and collection of water and household water quality

Table 2 shows results of the influence of water source and water collection method on household water quality. About 96% of the households involved in this study used pipe borne water. However about 57% of these were not located in the house of the households. The source of water had significant relationship with household water quality ($p=0.049$) with 76.2% of respondent who use pipe-borne water having water of good quality. The percentage of households with quality water source was significantly higher among those who have in-house water source rather than those who fetch water from outside public stand pipes (25.4% versus 9.9%; $p=0.009$). Household water quality was also influenced by distance to water source ($p=0.042$) but not with time spent to get water and containers used for collection water from source, Table 2.

3.3 Water storage, household sanitation practice and water quality

As shown in table 3, household water quality in the metropolis was significantly influenced by the place of water storage ($p=0.032$). Items used for storing water in the metropolis included metal drums (38.6%), plastic drums (20.5%), poly/sintex tanks (5%), earthen ware pots (29.5%) and aluminimum pots (3.5%). The results also shows a significant association between duration of water storage and the quality of household water ($p=0.025$). The percentage of households with quality water was higher among respondents who had toilet in the house than those who did not although this relationship was not significant. The frequency of cleaning storage container and what is used in cleaning the storage container all had no significant association with household water quality.

Table 4 presents a stepwise multivariate regression analysis of the extent of influence of the various independent variables on the quality of water among the sub metros under study. The model 1 presents analysis of the influence of household water source and collection on the water quality. The model 2 assessed the combined influence of the household water source /collection and the household water storage as well as the influence of the residence of respondents on the quality of water. The source of water for household consumption and distance to source of water showed significant relationship with household water storage in model 1. Household's with water source outside their homes were less likely to have quality water (OR=0.19; $p<0.01$). Holding all variables constant, respondents who traveled 100 to 500m to water source were less likely to have quality water in their household with respect to respondents who travel shorter distances (OR= 0.48; $p<0.05$). A similar association was observed in the model 2 where all other factors were controlled for (OR= 0.62; $p<0.05$). The place of water storage also had significant association with household water quality, Table 4.

4. Discussion

This study was designed to assess the factors influencing household water quality at the Tamale Metropolis in the Northern Region Ghana. The lack of clean drinking water and sanitation systems is a severe public health concern in Ghana, contributing to about 70% of diseases in the country. Consequently, households without access to clean water are forced to use less reliable and unhygienic sources (AfDB/ OECD, 2007). The quality of water for household consumption was measured by the presence of feacal coliforms and E coli in tested samples. Majority of the tested samples had feacal coliforms of more than 10 counts per ml and 83% tested positive for E coli. This indicates a low quality of household water for consumption among studied households and unsafe for household consumption.

Differences in socio-demographic characteristics might play a role in water quality of the household (McGarvey et al, 2008). While McGarvey et al (2008) in their study of household water quality in coastal Ghana found a positive relationship between household size and the presence of E.coli, our results are rather contradictory as we found that educational levels and household size did not show significant influence on household water quality. Water quality in the Metropolis might be dependent of other factors relating to acquisition and storage rather than household characteristics.

The sources of household water in our study areas were mainly pipes, boreholes and unprotected deep wells. The quality of water was 76.2% for pipe borne water, 43.1% for borehole and 35.9% protected deep well. Results in the study indicates that protected deep wells had significantly more E.coli (64.1% of tested samples) as compared to boreholes (56.9% of tested samples) and was low in pipe borne water (23.8%). Albert et al (2010) in their study to determine the quality of water at the point of use (POU) also discovered that standpipe (tap) water and harvested rainwater had significantly less E. coli than surface waters (earth pan and river). The water supply and sanitation sector in Ghana faces a number of challenges, including very limited access to sanitation, intermittent supply, high water losses and low water pressure and therefore cannot meet the demand from all households to be supplied with tap water. This situation is not limited to Ghana alone. Advocating for simple storage and purification strategies will help improve water quality at the household level. Many homes in Ghana tend to fetch water outside their domestic homes for use. Developing areas may sometimes be supplied with tap water but the distribution system does not follow the normal regulation of the taps built in-house, but rather communal taps which often are some distance from the main house (Jagals, 2006). In this study, some households were traveling 500m to source of water. Frenierre (2009) also indicated that at some instances, people walk between 5 and 10km to get to source of water. Distance to the facility had significant influence on water quality in this study with quality being higher among those who collect water from a short distance. A recent estimate reveals that about 52% of the population traveled half an hour or more to collect water every day (CSA, 2006).

Previous studies have shown that the bacteriological quality of drinking water significantly declines after collection (Wright et al, 2004), suggesting that safer household water storage and treatment (point-of-use) should be the recommended focus of intervention efforts (Clasen & Bastable 2003; Gundry et al, 2004). As a result of the non-availability of a constant provision of water for households, individuals tend in one way or the other to store water in containers for future use. The type of container used for the storage of household water can determine the wholesomeness of the water at the point of use. Levy et al (2008) established that, the type of storage container used for storing water at the household level could also influence the outcome of the water. The containers for household water storage in the metropolis included metal drums, plastic drums, poly tanks, earthen ware and aluminum pots. Pots, metal buckets, plastic buckets, jerry cans, plastic basins, barrel/drums, cooking pots/saucepans were also cited as storage containers in a study by Kumwenda (2009). In this study, type of containers significantly influenced the quality of water consumed by the household. This is consistent with previous studies showing that factors related to the container, such as large versus small mouth and covered or uncovered, are key factors in determining quality of stored water (Mintz et al, 1995). The study by Brick et al (2004) also found significant association between storage container and level of microbial contamination. The influence of water storage on microbial levels was also evident in the interventional study by Sobsey et al (2003), where *Escherichia coli* levels in stored household waters were <1/100 mL in most intervention households (household water chlorination and storage in a special container) but readily detectable at high levels in control households. Lautenschlager et al (2010) also measured the effect of stagnation on water quality and found out that cell concentrations, measured by flow cytometry, increased in all water samples after stagnation. This increase was also observed in adenosine tri-phosphate (ATP) concentrations and heterotrophic plate counts.

Despite the availability of cleaner water from taps, boreholes and tanks, problems are often experienced with accessibility and availability of the supply water (Jagal, 2006). This scarcity and inconsistency in the supply of portable water especially in developing countries leads to the inevitable practice of households storing water for future use in containers. The level of duration can also increase the risk of household water contamination and provide breeding grounds for mosquitoes - which are carriers of dengue fever, malaria and other diseases (Jajal, 2006). Momba and Mnqumevu (2000) in their study revealed that households could store water for a duration ranging from 1-2 days, 3 days, a few hours and up to 7 days. In this study, microbial contamination was significantly higher among water stored for more than a month as compared to storage periods of 1-3 days and 1 – 2 weeks. This was consistent with the study by Brick et al (2004) where on household storage, 25/37 (67%) of freshly pumped water showed increased contamination during storage periods from 1to 9 days. However, it is well known that the materials used for the distribution system or storage and the exposure time have an impact on the microbial quality of water. Perhaps, it would be much safer to store water for very short periods as possible to prevent deterioration of drinking water Momba and Mnqumeve (2000).

Limitations of the study

This study might not have investigated all necessary household factors that might influence the quality of water in the household. The study did not access data on sanitary practices that could influence the quality of water in the household. Previous studies indicate the importance of sanitary habits and the possible contamination of household water in storage vessels. It was however assumed that the various factors studied were equally important in determining the factors influence household water quality. Seasonal changes could also impact on the quality of water in the household for those who were not relying on pipe-borne water and this might have influenced the level of water quality measured. Lastly, the study might have suffered some information bias as translating the questionnaire from the English language to Dagbani (native language of the study area) could have created some gaps.

5. Conclusions

About 83% of the tested samples had E coli present and majority had feacal coliforms. This indicates that the quality of water is low in the metropolis and this could have various health concerns for residents in the metropolis. This could however also be due to the fact that people are storing water in various forms and that is affecting the quality. Increased efforts to improve water supply in terms of quantity and quality to all households might help solve these. The low quality level however could also be due to the source of water. Households should therefore be taught simple purification strategies to help improve water quality at the household level. Advocates of point–of-use disinfection of household water should be encouraged to enhance the quality of water in households to prevent deterioration. For instance, the use of the locally manufactured ceramic filters could be encouraged at home at least to take care of water for drinking. With the current water problems facing Urban Water Company and their current capacity, making it impossible to distribute water to every household in the country; there should be an advocate for use of appropriate containers that will minimize microbial growth.

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Table 1: Bivariate analysis showing the influence of socio-demographic factors on household water quality

variables	Water quality		Chi Square(X^2)	p-value
	Quality (%)	Not quality (%)		
Level of education				
– Literate	38.5	43.9	3.11	0.063
– Non-literate	61.5	56.1		
Household size				
– 1-10	14.3	85.7	2.466	0.651
– 11-20	23.8	76.2		
– >20	13.8	86.2		

Table 2: Bivariate analysis showing the influence of water source and collection method on household water quality

Variables	Water quality		Chi Square(X^2)	p-value
	Quality (%)	Not quality (%)		
Source of domestic water				
– Pipe	76.2	23.8	5.673	0.049
– Borehole	43.1	56.9		
– Protected deep well	35.9	64.1		
Source of water in house				
– Yes	25.4	74.6	6.73	0.009
– No	9.9	90.1		
Distance to water source				
– 10m – 50m	23.0	77.0	839	0.042
– 50 - 100m	11.8	88.2		
– 100 – 500m	10.0	90.0		
Time spent to get water				
– <3omins	12.2	87.8	0.896	0.639
– 30mins - 1hour	6.7	93.3		
– 1hr- 2 hrs	3.1	96.9		
Container to collect water from source				
– Basin	27.0	73.0	5.969	0.201
– *Gariwa*	11.6	88.4		
– Jerry cans	27.3	72.7		
– Buckets	11.2	81.8		
– Others	8.3	91.7		

Table 3 Results of bivariate analysis showing the influence of water storage and household sanitation practices on water quality

Variables	Household water		Chi Square (X^2)	p-value
	Quality (%)	Not Quality (%)		
Place of water storage				
– Metal drums	16.7	83.3	13.789	0.032
– Plastic drums	34.6	65.4		
– Poly/ sintex tank	8.9	91.1		
– Earthen ware pots	17.5	82.5		
– Aluminum pots	6.7	93.3		
Duration of water storage				
– 1 – 3 days	16.9	83.1	4.155	0.025
– 1 week – 2 weeks	9.1	90.9		
– More than a month	33.3	66.7		
Toilet in house				
– Yes	25.9	74.1	2.124	0.145
– No	14.5	85.5		
Type of toilet in house				
– Water closet	22.2	77.8	1.9259	0.382
– KVIP	33.3	66.7		
– Enviro Loo	-	-		
Frequency of cleaning storage container				
– Everyday	8.6	91.4	5.3719	0.497
– Once a week	21.7	78.4		
– Once a month	15.4	84.6		
What used in cleaning storage container				
– Water only	26.7	73.3	3.3912	0.907
– Water and soap	17.4	82.6		
– Water, soap and sponge	18.4	81.6		

Table 4: Results of regression analysis of influence of water source, collection and storage on household water quality

Covariates	Model 1 OR (95% CI)	Model 2 OR (95% CI)
I. household water source/ collection		
Source of domestic water		
– Pipe	1	1
– Borehole	0.11 (0.02, 0.99)	0.32 (0.07, 0.75)*
– Protected deep well	0.58 (0.22, 1.87)	0.65 (0.11, 2.93)
Source not located in house	0.19 (0.04, 0.97)**	0.12 (0.02, 0.25)
Distance to water source		
– 10 – 50m	1	1
– 50 – 100m	1.14 (0.44, 2.91)	1.21 (0.44, 3.33)
– 100 – 500m	0.48 (0.08, 0.74)*	0.82 (0.45, 0.98)*
– >500	0.42 (0.10, 1.31)	0.67 (0.16, 1.92)
Time taken to get water		
– Less than 30mins	1	1
– 30mins – 1 hour	0.38 (0.10, 1.50)	0.25 (0.05, 1.23)
– 1hour - 2 hours	0.01 (0.00, 0.20)	0.01 (0.00, 1.17)
– >2 hours	-	-
Container to collect water		
– Basin	1	1
– Gariwa	0.56 (0.25, 1.28)	0.57 (0.22, 1.47)
– Jerry cans	1.40 (0.31, 6.41)	1.42 (0.28, 7.15)
– Buckets	0.57 (0.06, 5.41)	0.50 (0.05, 5.48)
II. Household water storage		
Place of storage		1.34 (0.95, 1.88)*
Duration of storage		
– 1-3 days		1
– 1 week – 2 weeks		2.15 (0.73, 6.38)
– More than a month		1.01 (0.17, 5.88)
III. Sub-metro		
– Tamale North		1
– Tamale Central		2.31 (0.78, 6.81)
– Tamale South		0.71 (0.19, 2.64)
Number of observations	228	215
Log likelihood	-90.479	-73.674
Prob> chi2	0.0020	0.0034

p<0.05; **p<0.01; (-) omitted; main outcome = water quality